Bonneville Power Administration
Fish and Wildlife Program FY99 Proposal

Section 1. General administrative information

Monitor And Evaluate Modeling Support

Bonneville project number, if an ongoing project 8910800

Business name of agency, institution or organization requesting funding
University of Washington

Business acronym (if appropriate)

Proposal contact person or principal investigator:

Name	James J. Anderson
Mailing Address	1325 - 4th Ave., Suite 1820
City, ST Zip	Seattle, WA 98101
Phone	206-543-4772
Fax	206-616-7452
Email address	jim@fish.washington.edu

Subcontractors.

Organization	Mailing Address	City, ST Zip	Contact Name

NPPC Program Measure Number(s) which this project addresses.

NMFS Biological Opinion Number(s) which this project addresses.
Program Support & NMFS BO RPA A1f; A13; A17

Other planning document references.
0.3.b.

Subbasin.

Short description.
Provide analytical tools and databases required to evaluate the effectiveness of hydrosystem operations and other mitigation measures for improved fish survival as required to meet obligations of the ESA, NEPA, and NW Power Act.

Section 2. Key words

Mark	Programmatic Categories	Mark	Activities	Mark	Project Types
X	Anadromous fish		Construction		Watershed
	Resident fish		O & M	+	Biodiversity/genetics
	Wildlife		Production	+	Population dynamics
+	Oceans/estuaries	X	Research	X	Ecosystems
+	Climate	+	Monitoring/eval.	+	Flow/survival
	Other	+	Resource mgmt	+	Fish disease
			Planning/admin.	+	Supplementation
			Enforcement		Wildlife habitat en-
			Acquisitions		hancement/restoration

Other keywords.
life history, modeling, bubble disease, ecological interactions.

Section 3. Relationships to other Bonneville projects

Project #	Project title/description	Nature of relationship
9700200	PATH-UW Technical Support	Our specific tasks involve mainstem passage issues, effects of the ocean and estuary on survival, and harvest issues.
8910700	Epidemiological Survival Method	Information from this project is used to calibrate and validate the CRiSP models.
	Modeling Support for the U.S. Army Corps of Engineers	The Army Corps DGas project is evaluating the impacts to fish of the total dissolved gas produced from spill. The project is developing way to mitigate the impacts of spill. We are using their results to improve CRiSP algorithms and calibration.

Section 4. Objectives, tasks and schedules

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Modeling and analysis of smolt migrations through the river	a	Formulation of movements of water quality properties.

	system		
		b	Develop fish passage in terms of flow and fish behavior as determined by fish experiences and physiology
		c	Calibration of new elements of the model with new data such as fish growth and stress measures
		d	Model predictions will be validated by comparison with PIT tag studies and radio tracking studies on travel time and survival
2	Analysis and modeling of adult migrations	a	Adult passage in terms of flow and fish behavior as determined by fish experiences and physiology
		s	Calibration of fish dam passage and swimming behavior with radio tag data
		c	Predictions will be validated with radio tracking studies (provided by University of Idaho NMFS project) and historical estimates of inter-dam loss
3	Development of a selective stock harvest model	a	Implementation of the OSCUR surface current model into the Harvest model framework
		b	Develop the bioenergetic and behavioral components of the ocean migration of salmon and include in the Harvest model
		c	Develop a calibration procedure in a Bayesian analysis framework
4	Real-time analysis of smolt and adult passage	a	Maintenance of database and World Wide Web tools for real-time analysis
		b	Model the mixing and movement of gas and temperature distributions using the latest version of the CRiSP 1.x passage model
		c	Model the movement and exposure of smolts to gas, temperature and predators using CRiSP1
		d	Model the movement and exposure of adults to gas, temperature and

			harvest using the adult passage model
		e	Conduct a post-seasons analysis comparing model forecasts to observed distributions

Objective schedules and costs

Objective #	Start Date mm/yyyy	End Date mm/yyyy	Cost %
1	10/1997	9/2003	25.00%
2	10/1997	9/2002	25.00%
3	10/1997	9/2003	25.00%
4	10/1997		25.00%
			TOTAL 100.00%

Schedule constraints.

Completion date.
Ongoing.

Section 5. Budget

FY99 budget by line item

Item	Note	FY99
Personnel		224,806
Fringe benefits		51,390
Supplies, materials, non-expendable property		9,092
Operations & maintenance		$19,094
Capital acquisitions or improvements (e.g. land, buildings, major equip.)	office lease	$20,410
PIT tags	# of tags:	
Travel		$1,750
Indirect costs		$79,594
Subcontracts		
Other	tuition fees	$4,710
TOTAL		$410,846

Outyear costs

Outyear costs	FY2000	FY01	FY02	FY03

Total budget	$400,000	$400,000	$400,000	$400,000
O&M as % of total	47.00%	47.00%	47.00%	47.00%

Section 6. Abstract

The University of Washington provides support to BPA and the region for modeling and evaluation of the impact of Columbia and Snake River hydrosystem operations and salmon recovery plans on fish migration and survival. The work is focused in four areas: 1) river passage of juveniles and adults, 2) harvest, 3) ocean climatic effects on fish survival and 4) within-season real-time management of juvenile downstream passage and adult upstream passage.

The goal is to assist the region in developing the ability to identify and assess key alternative hypotheses relating to Columbia River salmon ecosystem dynamics and to move towards stock recovery and rebuilding. This project is relevant in that it will provide tools to conduct a scientific ecosystem-based evaluation of the impacts of specific fish and wildlife program actions.

Specific objectives include: development of adult and juvenile passage models, development of a multispecies selective stock harvest model; development of water quality model, within-season analysis of juvenile and adult river passage, and maintenance of a second tier database. The approach is multifaceted involving qualitative descriptions, data statistical correlations, Bayesian maximum likelihood estimation techniques, and mechanistic models. Three models will be completed in the project period: 1) the water quality model, 2) the upstream migration model and 3) the selective stock harvest model. The adult and juvenile in-season management will be implemented through World Wide Web tools.

The ability of the in-season projections will be evaluated through a comparison of preseason and within season projections of water quality, and fish passage in a post season analysis comparing predictions to observed measures. The harvest model will be evaluated through calibrations to CWT data.

Section 7. Project description

a. Technical and/or scientific background.

Calibrated and validated mechanistic based models are required to scientifically manage the Columbia/Snake River fisheries. These models must be accessible and usable by scientists, hydrosystem and fish managers and the public so the basis for the decisions and the implications of the decisions can be reviewed and understood by stakeholders. The UW project has developed these types of models for eight years to aid management of the river system. Significant past accomplishments include:

The Columbia River Salmon Passage Model (CRiSP1) is a smolt passage model which is currently in version 5. This model simulates the downstream migration and survival of smolts. Factors affecting passage include flow, temperature, dam operations, spill and gas bubble disease. A critical component is fish migration behavior. The factors controlling the rate of migration have been published in peer-reviewed literature (Zabel and Anderson 1997; Zabel et al. in press and calibrated are included in CRiSP1.5. The model is also stochastic, incorporating measures of variability and uncertainty into survival predictions. The model was calibrated dam passage studies and predator consumption studies. It has been validated against survival and travel time studies conducted between 1966 and 1997.

CRiSP 1.6 passage model includes two water quality indicators: temperature, and total dissolved gas supersaturation. Movement of anomalous parcels of water from spill or release of lower temperature water from storage reservoirs are modeled through the free flowing river and reservoirs using water mixing equations. The gas generation properties of all Columbia and Snake River dams have been calibrated and included in the model. Results of the fit of observed gas levels collected by the USACE and the predicted levels of gas from CRiSP1.6 are available on the World Wide Web at http://www.cqs.washington.edu/d_gas.

Biologists, managers and others interested in the river system can use this interactive CRiSP1 tool to evaluate the effects of river operations on smolt survival. Full details are available from the CRiSP Manual (Anderson et al. 1995). The manual and model (version 1.5.4) for Windows 95 and can be obtained on the World Wide Web at http://www.cqs.washington.edu/crisp/crisp.html.

The CRiSP Harvest Model (CRiSP2) is a user-friendly computer model that simulates the harvest of 30 chinook salmon stocks by 25 fisheries over an extended time horizon. The geographic range covered by the model extends from Southeast Alaska to the Oregon coast. Ten stocks and two fisheries from the Columbia River basin are included in the model. This is freely distributed software. The manual and model for Windows 95 can be obtained from the World Wide Web (http://www.cqs.washington.edu/crisp/crisp2pc.html). The model is now being extended to include the ocean migrations of salmon. With this capability the model can be used to evaluate harvest policies the selectively target strong and hatchery stocks and minimize the harvest on ESA stocks.

Data Access in Real Time (DART) is a World Wide Web based interactive data resource designed for research and management purposes relating to the Columbia Basin salmon populations and river environment. Currently, daily data plus historic information dating back to 1962 are accessible on-line. DART focuses on the Columbia Basin dams and fish passage. Detailed information is brought in daily from federal, state and tribal databases to provide a comprehensive information tool. DART generates user-specified data files which can be saved to a user's personal directory in a variety of formats designed to be compatible with most spreadsheet programs. In addition, DART has graphing capabilities which allow for the visual comparison of multiple variables on one

plot. These output formats are available for data resources related to fish passage, PIT tags and the river environment.

In-season forecaster is a composite model, known as CRiSP/RealTime, that predicts the arrival distributions and fraction transported at downriver projects - Little Goose, Lower Monumental, Ice Harbor, and McNary Dams. The system was developed jointly with BPA project Epidemiological Survival Methods and Columbia River Basin Including Individual EAS Demes (8910700, 9105100). Predictive runs in 1996 and 1997 were made weekly and published on World Wide Web pages. The model system takes as inputs fish releases, generated by RealTime, and flow and spill forecasts from BPA. The latter are also used to project temperature and gas profiles in the river. The model also simulates exposures to fish to gas and temperature and the survival of fish through the hydrosystem.

A prototype adult upstream migration model has been developed which simulates the impacts of dam operations, flows, and temperature on upstream migration of adult salmon. The model incorporates the river environment and dam operation components from the CRiSP downstream passage model but has separate algorithms to describe upstream migration. The main components of the model are reservoir passage, dam passage route and delay, dam fallback, mortality, migratory route and straying, and harvest. The data structure is designed to be compatible with the chinook harvest model being developed by NMFS and University of Washington Columbia Basin Research (CBR) scientists. The model can be run on either PC or Unix-based systems.

The effects of water temperature on timing and size of emergence of fry from redds has been developed showing that spawning choices for spring and fall chinook can be optimized by matching egg growth dynamics to river temperature patterns (Beer 1996; Beer and Anderson 1997).

b. Proposal objectives.

Objective 1: Modeling and analysis of smolt migrations through the river system

Completion and calibration of a smolt passage model for spring and fall chinook and steelhead including the temporal spatial exposure of fish to gas and temperature parcels is anticipated. Hypothesis: smolt travel time depends on river conditions and smolt growth and vitality. Passage mortality depends on cumulative stress, predators, and river conditions and fish growth. This objective also involves simulation of water quality including temperature and total dissolved gas. The analysis will allow the simulation and analysis of the cumulative exposure of smolts to high levels of gas and temperature. Algorithms to describe cumulative impacts of stress on fish mortality through the hydrosystem, in transportation and during estuary entrance will be implemented through a survival equations based on fish vitality.

Products: Smolt passage model calibrated and validated for chinook and steelhead, Evaluating the impacts of hydrosystem operations (transportation, drawdown and dam

removal) on smolt passage. CRiSP 1.7 smolt model will be available by down loading from the World Wide Web.

Objective 2: Analysis and modeling of adult migrations

Completion of adult passage model development and calibration is anticipated including evaluation of the impacts of drawdown and dam removal and exposure of adults to critical gas and temperature levels. Hypotheses: migration rate depends on flow, water quality, hydrosystem operations and fish condition and survival depends on legal and illegal harvest, and passage mortality.

Products: Adult passage model calibrated and validated for chinook and steelhead, evaluating the impacts of hydrosystem operations (spill, flow, drawdown and dam removal) and river harvest on passage. Adult model will be available by down-loading from the World Wide Web.

Objective 3: Development of a selective stock harvest model

Work on a multispecies selective stock harvest model will continue. This new modeling approach combines within-season migration of fish with harvest and gives managers the ability to design harvest policies that minimize the harvest of endangered stocks. The model will be developed in a Bayesian framework, so outcomes of harvest policies are expressed in probabilistic terms. Fish migration will depend on fish behavior and climate driven currents.

Hypotheses: Information on the movement of salmon stocks within a season can be used to develop selective stock harvest policies. Fish movements can be characterized in terms of movement matrices based on CWT data or on individual-based salmon movement algorithms driven by a surface current model. Harvest within each harvest region can be closed when the weak or endangered stocks move through the area.

Products: A stock specific harvest model will be developed and implemented on the World Wide Web that will allow development of time-dependent ocean harvest policies to minimize the harvest of endangered and threatened stocks.

Objective 4: Real-time analysis of smolt and adult passage

In-season realtime analysis of the passage of smolts and adults through the hydrosystem will be implemented through a web based tool. The system will track fish and water quality measures over the season. Preseason forecasts of flow and hydro operations will be input to the CRiSP water quality, smolt and adult passage models to predict the conditions of the river over the migration season and the exposure of fish to gas, water velocity, spill and water temperature patterns. Through the models, cumulative exposure patterns will be predicted over the year for smolts and adults. As the season progresses, real-time flow, temperature and gas information are used to update the forecasts for the remainder of the season. The models will also predict run timing of smolts and adults through the hydrosystem and the expected survival of each. Through a scenario tool, a World Wide Web user will be able to evaluate the impact of different hydrosystem operations on the fish migrations.

Products: Web based tool to track water quality, smolt passage adult passage in season. Report comparing predictions to post-season results.

c. Rationale and significance to Regional Programs.

The UW project provides essential modeling capabilities for the region to explore alternative hypotheses, for evaluating future harvest policy and for optimum management of the hydrosystem for smolt and adult river passage. Rationales of the specific objectives are stated below.

Objectives 1 and 2 concern analysis of smolt and adult migrations through the river system and involve calibration and validation of movement, survival and exposure of the fish to critical water quality indicators. These tools allow managers to evaluate the impacts of hydrosystem operations including flow augmentation, temperature control and spill on fish through a several measures that affect their survival and migration.

The development of the passage model is guided by results of projects studying the passage of juveniles and adults through the river system. The field studies are used to guide the development of the model structure and the model calibration.

Objective 3 involves developing a multi-species selective stock harvest model and analyzing the impacts of ocean conditions on stocks. With this tool managers can develop and evaluate policies to minimize the harvest of endangered stocks by targeting harvest reductions to endangered stocks when they are in specific fishing districts. The model will also accept as inputs long range climate forecasts, which will then modify oceanic distributions and consequently fish migration patterns and early ocean entry survival. With this capability managers will be able to evaluate the long term harvest policies with constraints from long term climate predictions.

This project is cooperative with an advisory/observer board consisting of federal state and tribal fisheries agencies (National Marine Fisheries Service, Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, Alaska Department of Fish and Game, Canadian Department of Fisheries and Oceans, Northwest Indian Fish Commission, and the Columbia River Intertribal Fish Commission) The model development also involves working relationships with scientist associated with the Global Ecosystem Dynamics project (GLOBEC) and through the North Pacific Marine Science Organization (PICES). Information and guidance from these organizations is essential for incorporating the most recent scientific information into the model. The project is also carried out with Dr. Newman at the University of Idaho.

Objective 4.The in-season prediction tools will provide managers with the most up-to-date projections of how hydrosystem operations affect water quality and fish migrations. These tools will assist managers in deciding how to allocate water resources, hydrosystem operations to meet the competing needs of spring and summer smolt migrants and adult migrants. The in-season analysis is conducted in cooperation with project 9105100 (Columbia River Basins including Individual ESA Demes).

d. Project history

The UW Monitoring and Evaluation Modeling support is a continuing project that was initiated in 1989. Major past accomplishments are outlined below.

1989-1991:

CRiSP.0 based on FISHPASS the BPA smolt passage model

CRiSP1.1 released -first version of the CRiSP 1 model

Published model on vitality-based organism survival

CRiSP training workshops held

Publications: Anderson (1991a, 1991b), Swartzman (1991).

1992:

CRiSP1.4 passage model with capabilities to run monte carlo simulations, mortality from supersaturation, calibrated for spring and fall chinook and steelhead.

Total dissolved gas and mortality modeling

Workstations installed at 6 agencies in the regions

Translated the Stochastic Life Cycle model developed by RFF into a UNIX version with a graphical user interface.

Participated in the System Operation Review (SOR)

Developed a flow archive data set accessible through the internet.

Training workshops were held for 25 regional scientists

Publications: Anderson (1992).

1993:

Workstations provided to region

Two model training workshops were held

Training workshops

Participated in the System Operation Review (SOR)

CRiSP2 harvest modeling project initiated (later becomes CRiSP Harvest)

CRiSP1.4 released with manual

Publications: Anderson (1993a, 1993b).

1994:

CRiSP 1.5.1 released

CRiSP2 released

Second Tier database system on-line with hydro operations, water quality information, and fish passage information on-line for user

World Wide Web page developed providing on-line access to the database through graphical interface and real-time predictions of in-season fish migration

Publications: Anderson (1994), Hinrichsen (1994), Zabel (1994).

1995:

DART Data Access in Real-Time was implemented on the World Wide Web

3 workstations were provided to regional agencies

28 regional scientists were trained in modeling workshops

Publications: Anderson (1995), Swartzman (1995).

1996:

DART Data Access in Real-Time was implemented on the World Wide Web

3 workstations were provided to regional agencies

28 regional scientists were trained in modeling workshops.

Publications: Beer (1996), Hyun (1996), Norris (1996).

1997:

CRiSP2 (Harvest) released on the World Wide Web

Publications: Anderson (1997) Beer and Anderson (1997), Lubetkin (1997), Zabel and Anderson (1997).

CRiSP1 total dissolved gas predictions implemented on World Wide Web

e. Methods.

In general, the contributions of the UW involve a range of analysis from qualitative descriptions of lifecycle stages to mathematical descriptions of the ecological mechanisms.

The tasks outlined above will use the analysis tools and models outlined in the objectives of project.

Objective 1: Modeling and analysis of smolt migrations through the river system

This involves calibration and validation of movement, survival and exposure of the fish to critical water quality indicators. The models will continue to be developed in a C++ cross platform (UNIX and Windows 95/NT) environment. Tasks involve:

-Task 1.a Formulation of movements of water quality properties. Critical assumption is that the movement of water quality indicators, (i.e. temperature and gas) are described by advective-diffusive equation in the passage models that move water parcels through the system.

-Task 1.b Develop fish passage in terms of flow and fish behavior as determined by fish experiences and physiology. Critical assumptions include the swimming behavior of smolts as a function of environmental conditions and physiology, and the use of vitality theory to describe the cumulative effects of stress on fish survival.

-Task 1.c Calibration of new elements of the model with new data, such as fish growth and stress measures.

-Task 1.d Model predictions will be validated by comparison with PIT tag studies and radio tracking studies on travel time and survival.

CRiSP 1 is highly developed model, calibrated against data and validated against independent data. The future work will involve further refinement of the model incorporating new information on the effects of stress, fish physiology, and bioenergetics in order to deal with the ever improving information being collected by the field programs studying mainstem and tributary passage. The predictions of the model will be evaluated in an interaction between updated calibrations and validations, where part of the data is used to validate the model and another part is used to compare the model predictions against other data. The model has been successful in predicting travel time and survival of spring chinook through the river system. It should do equally well for steelhead. In the case of fall chinook, however, because of the complexity and diversity of their migration, it is unclear how well the model will be able to simulate the evolving information.

Objective 2: Analysis and modeling of adult migrations

This involves the calibration and validation of movement, survival and exposure of the adult river migrating salmon to critical water quality indicators. This model component also be developed in a C++ cross platform (UNIX and Windows 95/NT) environment. Tasks involve:

-Task 2.a Adult passage in terms of flow and fish behavior as determined by fish experiences and physiology. Critical assumptions include the swimming behavior of adults as a function of environmental conditions and physiology.

-Task 2.b Calibration of fish dam passage and swimming behavior with radio tag data.

-Task 2.c Predictions will be validated with radio tracking studies (provided by University of Idaho NMFS project) and historical estimates of inter-dam loss.

The adult passage model is developed from first principles of fish swimming bioenergetics and observed fish behavior from radio tagged studies. The model will provide the region the first analytical tool to evaluate whether hydrosystem operations have a measurable impact on the upstream migration of adults. The modes will allow assessment of the cumulative exposure of adults to temperature and gas levels and will track, through bioenergetic considerations, the energy expended in upstream migration and will relate these measures to hydrosystem operations.

Objective 3: Development of a selective stock harvest model.

This involves describing ocean movements of fish through current regimes and fish behavior and physiology. The work will in part extend the studies of NERKAsim developed in Canada to explore the bioenergetic of Fraser River sockeye (Scandol, Rand, Walter 1996). The bioenergetic features of this model will be combined into the harvest capabilities of the CRiSP Harvest model being developed under a NMFS contract to the University of Washington.

This work involves analysis of the historical patterns of west surface currents using the OCSURS current model (Ingraham and R. K. Miyihara 1988) and the limited information on the distribution of predators and plankton available in historic records. The approach is to determine if any plausible patterns of currents and ecological regimes emerge from simulation analysis that can explain the decadal scale and latitudinal patterns of stock productivity from California to Alaska. If patterns can be recognized they can be used to better define climate interactions in the retrospective analysis and the results will be used to improve the simulation of climate in the prospective analysis.

-Task 3.a Implementation of the OSCUR surface current model into the Harvest model framework.

-Task 3.b Develop the bioenergetic and behavioral components of the ocean migration of salmon and include in the Harvest model.

-Task 3.c Develop a calibration procedure in a Bayesian analysis framework. In this task the physical oceanographic and physiological information and the Coded Wire Tag data are used to constrain the model parameter space for model simulation.

The stock selective harvest model will in theory provide considerable resolution of the distributions of stocks. Unfortunately, the CWT data base is not designed to resolve within-season detailed temporal spatial information so there is a miss-match between the model predictive abilities and the data resolution. To address these problems the model scales and migration algorithms will be constructed so they can be easily modified. For setting harvest policies, the model must use observed CWT data and consequentially its temporal-spatial resolutions will be crude resulting in an aggregated, within-season harvest policy. In an exploratory model, the fish migration measures can be extrapolated from fish bioenergetics and behavior coupled with currents predicted from sea-surface wind data and predictions in much the way that NERKAsim models sockeye migration and bioenergetics. The approach gives a theoretical distribution on detailed spatial and temporal scales. When configured in a Bayesian model this will allow fisheries managers the ability to assess the probability of the consequence of harvest policies. This exploratory model will be important to assess potential gains to endangered stocks at the potential expense of harvest restrictions on targeted hatchery and strong stocks.

Objective 4: Real-time analysis of smolt and adult passage.

-Task 4.a Maintenance of database and World Wide Web tools for real-time analysis.

-Task 4.b Model the mixing and movement of gas and temperature distributions using

the latest version of the CRiSP 1.x passage model.

-Task 4.c Model the movement and exposure of smolts to gas, temperature and predators using CRiSP1.x. Generate cumulative exposure measures, system survival and passage indicators.

-Task 4.d Model the movement and exposure of adults to gas, temperature and harvest using the adult passage model. Generate cumulative exposure measures, survival and passage indicators.

-Task 4.e Conduct a post-seasons analysis comparing model forecasts to observed distributions.

A critical assumption is that the modeling systems to predict smolt and adult passage and water quality measures provide valid representations of the processes. Evaluations of these assumptions are made by comparing the pre-season and within seasons predictions with observations. From the experience of the real-time predictions conducted in 1996 and 1997 we expect very close predictions of the migration. The major errors are expected to occur from the uncertainties in the early predictions of the seasonal run-off pattern.

f. Facilities and equipment.

The CRiSP project is conducted at the University of Washington off-campus due to the demolition of the CQS building on campus. Completion of this project involves maintenance of our library, computer facilities, and data bases. This information system is fully functioning in the Columbia Basin Research. Minor replacement of computer facilities and upgrading of software is anticipated, but no major high-cost equipment will be needed.

g. References.

Anderson, J.J. 1991a. Fish Bypass System Mathematical Models. (In press, WATERPOWER 91)

Anderson, J.J. 1991b. A Vitality Based Stochastic Model for Organism Survival. Proceedings of Conference on Individual Based Ecological Models. (In press)

Anderson, J.J., et al. 1992. Documentation for CRiSP.1 (Draft internal report)

Anderson, J.J., July 13, 1993. Report to the Snake River Salmon Recovery Team on an Analysis of Spring and Fall Chinook Survival using the CRiSP Mainstem Passage Model.

Anderson, J.J., October 6, 1993. Second Report to the Snake River Salmon Recovery Team on an Analysis of Spring Chinook Survivals using the CRiSP Mainstem Model.

Anderson, J.J., May 11, 1994. Evaluation of NMFS Spill Recommendation (Internal draft)

Anderson, J.J., May 13, 1995. Columbia River World Wide Web Group.

Anderson, J.J. 1997. Decadal Scale Climate Pattern and Salmon Survival: Indicators, Interactions and Implications, Estuarine and Ocean Survival of Northwest Pacific Salmon Workshop NMFS 1997.

Anderson, J. J. (in press). Decadal climate cycles and declining Columbia River salmon. Sustainable Fisheries Conference Proceedings.

Beer, W. N. 1996. A growth model for larval salmon with application to field and laboratory observations of chinook salmon (*Oncorhynchus tshawytscha*). Master of Science Thesis, University of Washington, Seattle, WA.

Beer W. N. and J.J. Anderson, 1997. Modeling the growth of salmonid embryos. Journal of Theoretical Biology. 189(3) 297-306.

Hinrichsen, R. 1994. Optimization models for understanding migration patterns of juvenile chinook salmon. Doctor of Philosophy dissertation. University of Washington, Seattle, WA

Hyun, S. Y. 1996. Ocean distributions of Columbia River Hanford Reach and Snake River fall chinook salmon (*Oncorhynchus tshawytscha*) stocks and the effect of interannual ocean conditions on their survival. Master of Science Thesis, University of Washington, Seattle, WA.

Ingraham, W. J, Jr. and R. K. Miyihara. 1988. Ocean surface current simulations in the North Pacific Ocean and Bering Sea (OSCURS-Numerical Model). NOAA Tech. Mem., NMFS F/NWC-130, 155 p.

Lubetkin, S. C. 1997. Multi-source mixing models: food web determination using stable isotope tracers. Masters of Science Thesis, University of Washington, Seattle, WA.

Norris, J.G., Defining Equivalent Harvest Rate Reduction Policies for Endangered Snake River Fall Chinook Salmon, (in press). Proceedings of the Sustainable Fisheries Conference, Victoria B.C. Canada, 1996. Eric Knudsen, Editor. Special publication of the American Fisheries Society.

Scandol, JP, Rand, PS, Walter, EE (1996). NerkaSim: An Interactive Spatially Explicit Individual Based Production and Migration Model of Sockeye Salmon in the North East Pacific. UBC Fisheries Centre, 2204 Main Mall, Vancouver V6K 1C5, CANADA.

Swartzman, G. 1991. Equilibrium Abundance of Salmon Stocks in a Life Cycle Model with Interacting Hatchery and Natural Substocks. (In press, Natural Resource Modeling, Volume 5, Number 1, Winter 1991)

Swartzman, G. September 26, 1995. Review of the Hungry Horse and Libby Reservoir Models.

Zabel, R.W. and J.J.Anderson. 1997. A model of the travel time of migrating juvenile salmon, with an application to Snake River spring chinook salmon. North American Journal of Fisheries Management. 17:93-100.

Zabel et al. (in press). A multiple reach model to describe the migratory behavior of Snake
River yearling chinook salmon (*Oncorhynchus tshawytscha*), Canadian Journal of Fisheries and Aquatic Sciences.

Section 8. Relationships to other projects

This project provides a framework in which to synthesize information from the FWP field studies which are evaluating ecosystem interactions, the flow/survival relationship and population dynamics. The models developed in this project are formulated and calibrated from information obtained from these field studies. The models provide a rigorous approach to evaluating the system wide impacts of individual actions and stages of the fish life-cycle. The project also has a close connection to the PATH in that many of the hyotheses being evaluated in PATH originate from the models developed under this project.

Section 9. Key personnel

The principal investigator for this project is Dr. James J. Anderson.

Curriculum Vitae: James J. Anderson

Associate Professor (WOT)
Fisheries Research Institute and Center for Quantitative Science in Forestry, Fisheries and Wildlife
College of Ocean and Fisheries Sciences

Office Address	**University Address**
Columbia Basin Research Puget Sound Plaza 1325 - 4th Ave., Suite 1820 Seattle, WA 98101-2509 Phone: 206-543-4772	Fisheries Research Institute Box 358218 Seattle, WA 98195 Phone: 206-616-9174

FAX: 206-616-7452
e-mail: jim@fish.washington.edu
http://www.cqs.washington.edu

Teaching Activities:

Graduate course in modeling organism dynamics (QSCI 551)
Graduate course in Ecosystem models (QSCI 550)

Students Receiving Degrees: Three in M.S. Fisheries, Two in M.S. Quantitative Ecology & Resource Management, and Two in Ph.D. Quantitative Ecology & Resource Management.

Current Research Projects:

Bonneville Power Administration (Funding level: $6 million): Developing computer models for management of Columbia River hydroelectric and fisheries agencies.

U.S. Army Corps of Engineers (Funding level: $600,000): Developing analysis and computer models for the impact of gas bubble disease on migrating salmon.

National Marine Fisheries Service (Funding level: $300,000):

1) Studying mortality processes of juvenile salmon in tributaries
2) Developing a multi-species multi-regional salmon harvest model

Honors and Awards:

1) Research Faculty Fellowship, College of Ocean and Fishery Sciences 1985, 1989.
2) Special Recognition for participation in the U. S. Fish and Wildlife Service Fish Passageways and Division Structures course in 1990.
3) Nomination for Computerworld Smithsonian Awards in programming for the CRiSP computer model College of Ocean and Fishery Sciences Distinguished Research Award, 1996.

Professional Activities: Consulting; Expert Testimony on Fish Migration and Dam Passage; Guest Speaker

There is a total of 47 Publications. The 1997 Publications include:

Anderson, J.J. (in press) Decadal Climate Cycles and Declining Columbia River Salmon. Proceedings of the sustainable Fisheries Conference, Victoria B.C., Canada, 1996. Eric Knudsen, Editor. Special publication of the American Fisheries Society.

Anderson, J.J. 1997. Decadal Scale Climate Pattern and Salmon Survival: Indicators, Interactions and Implications, Estuarine and Ocean Survival of Northwest Pacific Salmon Workshop NMFS 1997.

Beer, W.N. and J.J. Anderson. 1997. Modeling the Growth of Salmonid Embryos. Journal of Theoretical Biology. 189(3) 297-306.

Zabel, R.W. and J.J. Anderson. 1997. A Model of the Travel Time of Migrating Juvenile Salmon, with an Application to Snake River Spring Chinook. North American Journal of Fisheries Management. 17:93-100.

Section 10. Information/technology transfer

Models, documentation correspondence for this project are available on the World Wide Web at http://cqs.washington.edu. Selected works are published in the reviewed literature or as BPA reports.